DEVELOPMENT OF GROUND CONTROL STATION APPLICATION ON UNMANNED AERIAL VEHICLE BASED ON INTERNET OF THINGS

Fakhri Ramdani[1], Iskandar Ikbal[2]

[1,2] Program Studi Teknik Informatika-Universitas Komputer Indonesia
Jalan Dipatiukur 112-114 Bandung, Jawa Barat 40132
E-mail : fakhriramdani4@gmail.com[1], Iskandar.ikbal@email.unikom.ac.id[2]

ABSTRACT

Ground Control Station (GCS) is a monitoring station, so operators on the ground can monitor the condition of the Unmanned Aerial Vehicle (UAV) during the flight. Based on the results of an interview with Mr. Didit Andri Jatmiko, S.Kom., M.T. As chairman and supervisor of the Divisi Roket Unmanned System Indonesian Computer University that currently the available Ground Control Station can only cover a limited area so supervisors in the Laboratory cannot see the condition of the UAV directly and must wait for reports of test results from operators in the field. and Ground Control Station which is currently available in the Divisi Roket Unmanned System Indonesian Computer University can only monitor one UAV, so monitoring different UAVs requires different GCS and is considered to be less efficient because data logging for each UAV is separate. Therefore, as a Solution in this study, a Ground Control Station system based on the Internet of Things is proposed so that it has a wide coverage area so supervisors can conduct monitoring directly in a location separate from flight testing and can monitor many UAVs. The results of tests carried out on the device by testing the detection of each sensor used and have a difference that is not too large with the actual value or from similar sensors. And testing of tools when inside and outside the room obtained 80% success when tested indoors and 96% when tested outdoors. So that it can provide information about the attitude of the UAV well.
Keywords : Unmanned Aerial Vehicle, Ground Control Station, Internet of Things, monitoring

1. INTRODUCTION

Currently in Indonesia Unmanned Aerial Vehicle (UAV) technology which was originally developed for military needs has now begun to be developed for needs in other fields such as remote sensing, mapping the area, monitoring agricultural land, and sweeping in areas that are difficult to reach by humans.

Unmanned Aerial Vehicle (UAV) is a term used to represent flying objects with their own power supply that can be used repeatedly without being operated by humans directly in it. Almost all UAVs have Remote Control to control the UAV to avoid collisions due to failure when flying automatically.[1]

Because the UAV path is in the air it will be difficult for humans to monitor the condition of the UAV. Therefore a Ground Control Station (GCS) system was developed as a monitoring station, so that operators on land could monitor the condition of the UAV during the flight.

Ground Control Station is a monitoring and command station where operators on the ground can send mission orders and oversee the course of the mission and condition of Unmanned Aerial Vehicle (UAV) during the mission. [2]

Based on the results of an interview with Mr. Didit Andri Jatmiko, S.Kom., M.T. As chairman and mentor in the Unmanned System Rocket Division of the Indonesian Computer University said that currently in the Indonesian Computer University Unmanned System Rocket Division Laboratory the available Ground Control Station can only cover a limited area because it uses a radio network so that when testing the flight the UAV conditions can only be seen by the operator in the field so that supervisors in the laboratory cannot see the condition of the UAV directly and must wait for the test results from the operators in the field. Then each Ground Control Station that is currently available in the Unmanned System Rocket Division of the Indonesian Computer University can only monitor one UAV, so monitoring different UAVs requires different GCS and is considered to be less efficient because logging data for each UAV is separate.

Based on the problems that have been described, as a Solution in this study a system is proposed to connect UAVs to the internet network so that it has a wide coverage area so that supervisors can carry out monitoring directly in a location separate from flight testing. then builds a Ground Control Station (GCS) application capable of monitoring many Web-based UAVs so that they are easily accessed on various computer devices without the installation process and can be accessed by many users at the same time, which will display accurate UAV condition data in the form of location maps, text , charts and visual instruments of flight as information for operators in determining subsequent decisions and references for supervisors in evaluating the development of UAV Technology in the UNIKOM Unmanned System Rocket Division. Therefore in this study the authors take the title "**Development of Ground Control Station Application on Unmanned Aerial Vehicle Based on Internet of Things".**

2. RESEARCH CONTENT

2.1 Theoritical Basis

The theoretical foundation is a set of opinions, definitions or concepts related to the scope and matters discussed in conducting this research. In addition, the theoretical foundation makes it easy for researchers to explain and predict research results.

2.1.1 Application

In term of application is a ready-made program that is designed to carry out a function for the user or other applications and can be used by the intended target. Application software is a subclass of computer software that utilizes the ability of the computer directly to perform the tasks desired by the user.[3]

2.1.2 Unmanned Aerial vehicle

Unmanned Aerial Vehicle (UAV) is a term used to represent flying objects with their own power supply that can be used repeatedly without being operated by humans directly in it. Almost all UAVs have Remote Control to control the UAV to avoid collisions due to failure when flying automatically.[1]

2.1.3 Ground Control Station

Ground Control Station Application (GCS) which is a monitoring system can visualize the motion or attitude of a UAV while flying, data obtained from the UAV sensor will be received by the monitoring system and processed into visual form of motion or UAV attitude when flying.[2]

2.1.4 Internet of Things

Internet of Things (IoT) is the ability to connect smart objects and enable them to interact with other objects, the environment and other intelligent computing equipment through the internet network. IoT in its various forms has begun to be applied to many aspects of human life.[4]

2.1.5 Monitoring

Monitoring is the process of gathering and analyzing information based on indicators that are set systematically and continuously about activities / programs so that corrective actions can be taken to further improve the program / activity.[5]

2.2 Research Method

Research Methodology for developing this application using descriptive analysis method. Descriptive analysis method is a method that serves to describe or give a picture of the object under study through data or samples that have been collected as they are. This research method has two stages, namely the stage of data collection and the stage of software development:

2.2.1 Method of Collecting Data

1. Study of Literature

   Data collection is carried out by studying, researching, and studying various literature from libraries sourced from books, scientific journals, internet sites, and other readings related to the research conducted.

2. Interview

   At this stage the aim is to find answers about things that are not yet known by the author in this thesis to those who are more expert in developing systems on the UAV.

3. Observation

   This method is used to observe devices that will be used for Ground Control Station systems on Unmanned Aerial Vehicles, armed with information from literature studies that have been carried out.

2.2.2 Software Development Method

In making this application using the Prototype model as a stage of software development The process includes :

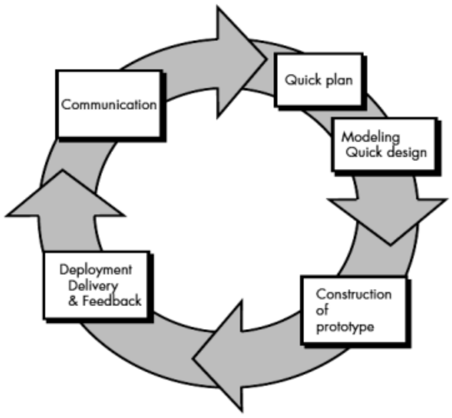


Figure 1. Prototype Model[6]

1. *Communication*

   At this stage communication is carried out with the user to define the overall objectives of the system and identify and analyze needs.[6]

2. *Quick Plan*

   Quick planning by analyzing the needs needed in building an IoT-based Ground Control Station for Unmanned Aerial Vehicle . [6]

3. *Modelling Quick Design*

   The process of making a design quickly to make an overview of the tools to be built. [6]

4. *Construction of Prototype*

   At this stage an evaluation is carried out in accordance with the needs of the results of the modeling that has been done. [6]

5. *Deployment Delivery and Feedback*
This stage is carried out with the development and testing of the system and if the user feels that it is not in accordance with the needs, it will be corrected until the user feels according to the needs.[6]

2.3 Results and Discussion

This following is a discussion of the Ground Control Station application that will be built with the results.

2.3.1. Analysis of System Architecture

Analysis of system architecture is the stage of describing the physical system to be built and also some supporting components.

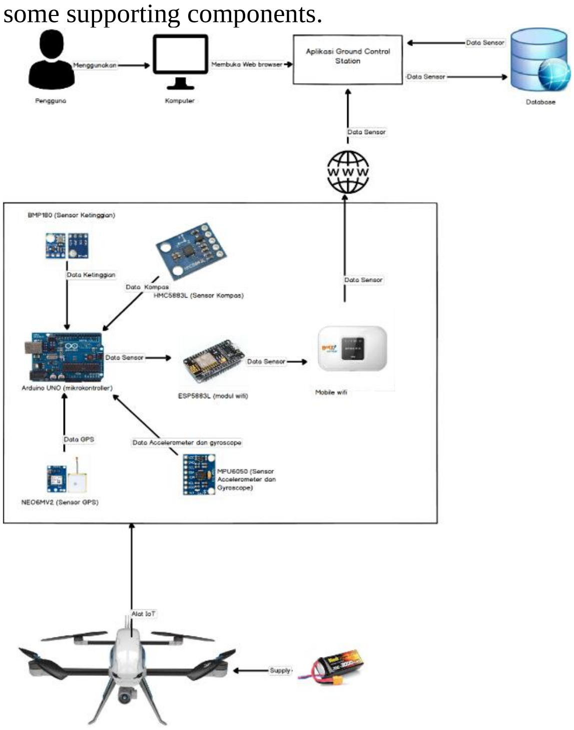


Figure 2. Architecture System

The following explanation from Figure 2:

1. The tool is placed in an Unmanned Aerial Vehicle that will collect data from the UAV.
2. Unmanned Aerial Vehicle sources come from batteries.
3. The microcontroller voltage source comes from a battery that has passed through the regulator and the voltage is changed to 5V.
4. Microcontroller used is 1, Arduino Uno.
5. Arduino Uno functions to collect data from sensors and connect it to a WiFi module to be sent to the internet.
6. The microcontroller will receive Attitude data in realtime from the Attitude sensor.
7. The microcontroller will receive Longitude and latitude data in realtime from the GPS sensor.
8. The microcontroller will receive the Altitude data in realtime from the Altitude sensor.
9. The microcontroller will receive real-time Heading data from the Compas sensor.
10. Data that is processed and sent to the internet by Arduino including Attitude, Altitude, Heading, Longitude and latitude data.
11. Web server consists of Apache web server and MySQL.
12. Data that has been sent to the internet is then stored in a database.
13. Users can use the browser on a computer to open the ground control station application.
14. Users log in to enter the Ground Control Station application.
15. Ground Control Station retrieves sensor data information stored in a database to be displayed in the form of visual maps, visual flight instruments, charts and text.

2.3.2 Analysis of the Sensor used

Here is an analysis of the sensors used in the IoT tool.

1. Attitude Sensor
The Attitude sensor used is a GY-521 sensor which is an Inertial Measurement Unit (IMU) module that uses the MPU-6050 chip from InvenSense. MPU-6050 itself is a chip with 3-axis Accelerometer (acceleration sensor) and 3-axis Gyroscope (regulating balance), or in other words 6 degrees of freedom (DOF) IMU. In addition, the MPU6050 itself already has Digital Motion Processors (DMP), which will process raw data from each sensor. Some of the data will be processed into data in the form of quaternions (4 dimensions). DMP on the MPU6050 also serves to minimize the resulting error.[7]

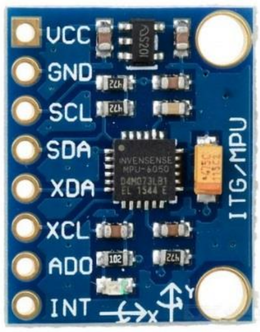


Figure 3. MPU6050

2. Heading Sensor
The Heading sensor used is the HMC5883L sensor which is a magnetic sensor packaged in a surface mount 3.0x3.0x0.9mm 16-pin leadless chip carrier (LCC). The HMC5883L is composed of high-resolution magnetic resistive sensors with automatic demagnetization, offset removal and a 12-bit ADC for measuring high-resolution

earth magnetic fields. Using Honeywell's magneto-resistive anisotropic (AMR) technology, the HMC5883L provides a higher level of precision on axis sensitivity and linearity and is designed to measure both the direction and magnetic field of the earth.[8]

Figure 4. HMC5883L

3. Altitude Sensor
   The Altitude sensor used is the BMP180 sensor which is a sensor that can measure barometric pressure using a digital barometer. The accuracy of this sensor reaches 1 meter. This sensor only requires 0.3 uA so it saves battery.[9]

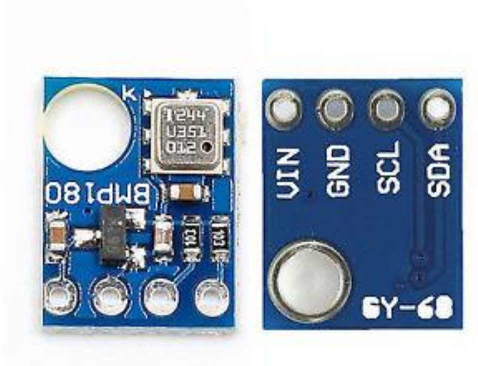


Figure 5. BMP180

4. GPS Sensor
   The GPS sensor used is the NEO6MV2 GPS Module, which is a GPS module that can work with Arduino Uno and Arduino Mega microcontrollers. This GPS module has a feature as a determinant of the location or position. UBLOX NEO6MV2 GPS is a GPS receiver with 50 channels. Time to First Fix in cold start requires 27 seconds, warm start takes 27 seconds, in hot start requires 1 second, Aided start takes less than 3 seconds. NEO6MV2 GPS has -130 dBm tracking sensitivity and Navigation, 0.25Hz - 10 MHz frequency of time pulse signal, and Max navigation update rate of 10 Hz. This module uses the NMEA protocol which is a protocol that is used by the GPS receiver. The output data of this module is ASCII code containing information on latitude, longitude, altitude, UTC standard time and speed over ground information..[10]

Gambar 6. NEO6MV2

2.3.3 Sensor Detection Analysis

Following is an analysis of how the application processes sensor data on the IoT tool..

1. Attitude Sensor
   Attitude detection uses the MPU6050 sensor to find out the attitude of an Unmanned Aerial Vehicle (UAV) when it is airborne. Utilizing the Accelerometer and Gyroscope, the sensor is placed parallel and attached to the UAV so that it moves to follow the movement of the UAV. The following description of Attitude detection from Unmanned Aerial Vehicle, can be seen in Figure 7.

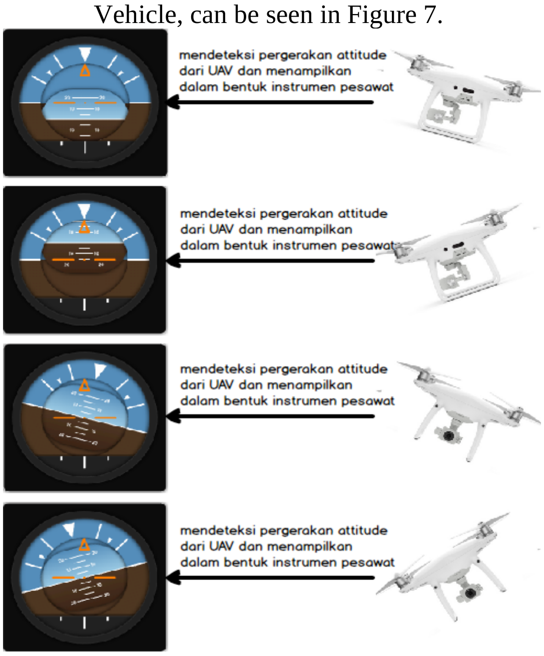


Figure 7. Deteksi Sensor Attitude UAV

2. Heading Sensor
   Detection heading uses HMC5883L sensor to determine the direction of the nose of the Unmanned Aerial Vehicle (UAV) according to the compass. The workings of this sensor are by determining the direction of the compass 0 ° - 359 °, which 0 ° indicates the north direction, 90 ° indicates the east direction, 180 ° is south, and 270 ° is the west direction. Following is an illustration of the detection of Heading from an Unmanned Aerial Vehicle, it can be seen in Figure 8.

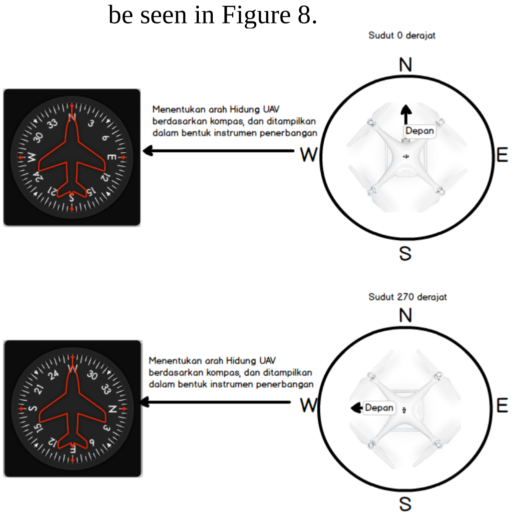


Figure 8. Heading Sensor Detection

3. Altitude Sensor
   Altitude detection uses a BMP180 sensor, to find out the height of an Unmanned Aerial Vehicle (UAV). The way the sensor works in processing altitude data is to utilize air pressure based on altitude to sea level. The following is an overview of Altitude detection from Unmanned Aerial Vehicles, can be seen in Figure 9.

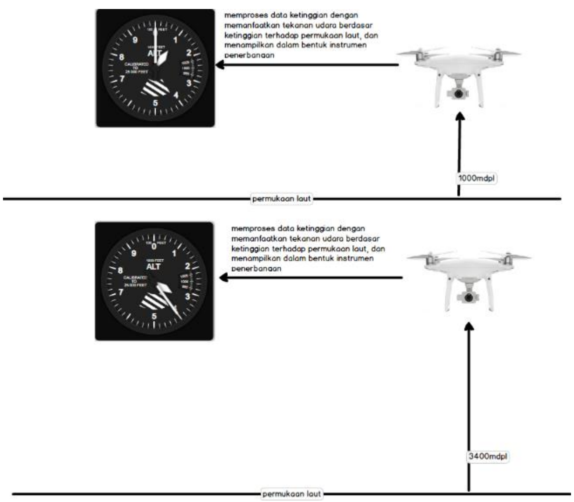


Figure 9. Altitude Sensor Detection

4. GPS Sensor
   Location detection uses the NEO6MV2 sensor, to find out the current location of the Unmanned Aerial Vehicle (UAV). The way this sensor works is by detecting the location by capturing and processing signals from navigation satellites. The following description of the location detection from Unmanned Aerial Vehicle, can be seen in Figure 10.

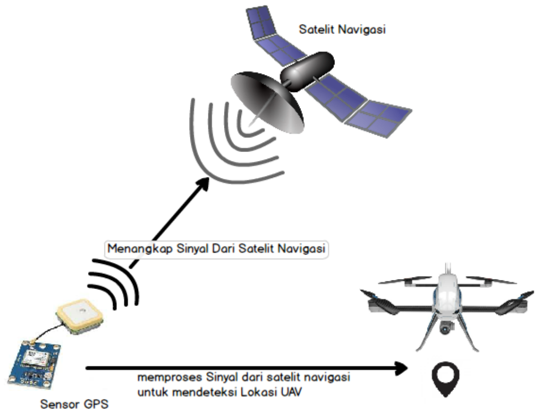


Figure 10. GPS Sensor Detection

2.3.4 Use Case Diagram

Use case diagram is a modeling for the behavior (behavior) of the information system that will be created. Use case is used to find out the function what is in the information system and who has the right to use these functions.

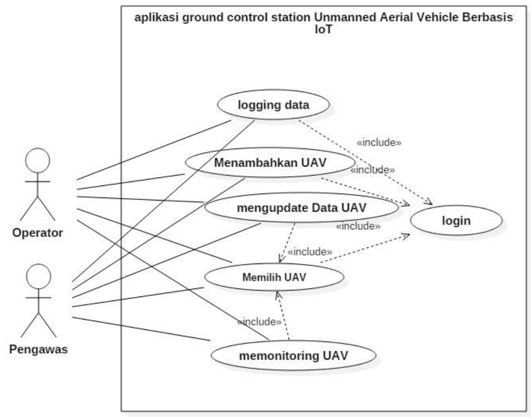


Figure 11. Use Case Diagram

2.3.5 *Class Diagram*

Class diagrams are static models that describe the structure and description of classes and their relationships between classes.

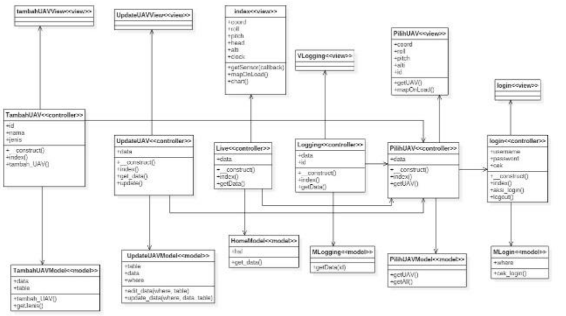


Figure 12. Class Diagram

2.3.6 Microcontroller and Sensor Implementation

Here in Figure 13 is the implementation of a series of components used on the system.

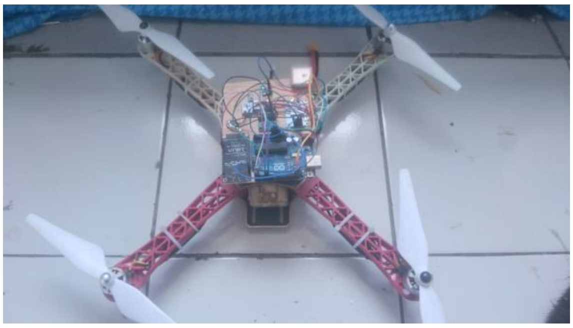


Figure 13. Component Implementation

2.3.7 Interface Implementation

Interface implementation is the construction of program views on the ground control station application. The following are the results of the interface design of the application that has been made:

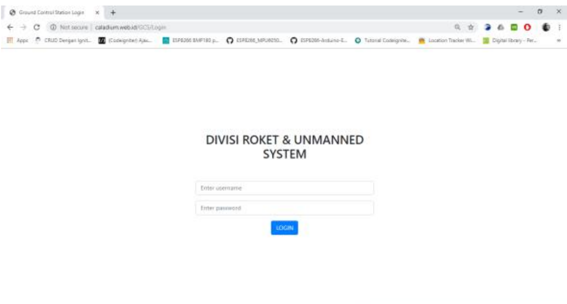


Figure 14. Login

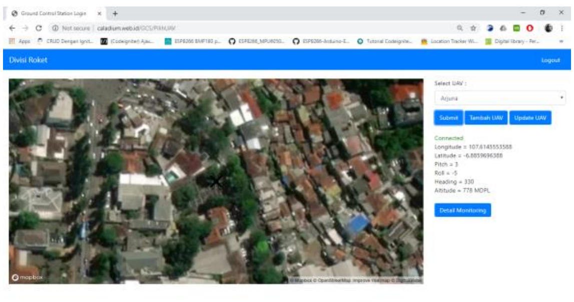
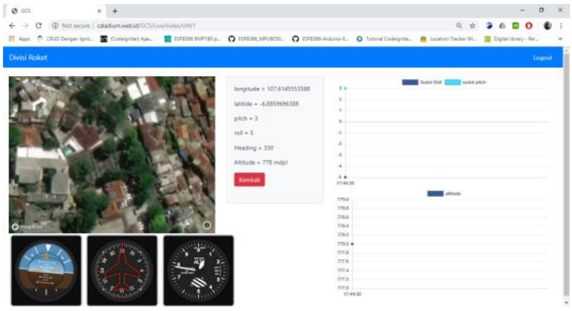
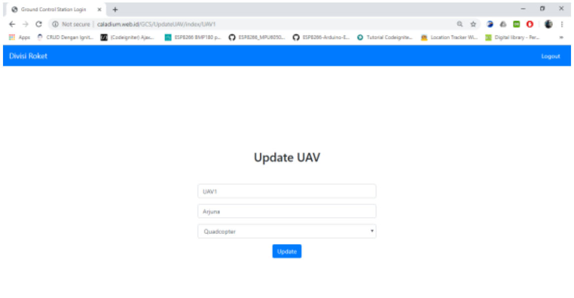


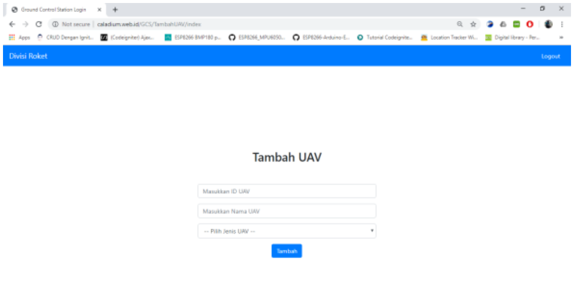
Figure 15. Select UAV



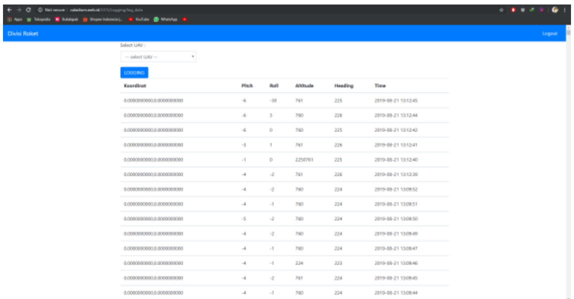
Gambar 16. monitoring



Gambar 17. Update UAV



Gambar 18. Add UAV



Gambar 19. Logging

2.3.8 Structural Testing

At this stage, testing is carried out to determine whether the structure of each component can be connected properly, so that the components can interact with each other well. The following structural testing can be seen in table 1.

Table 1. Structural Testing Table

System Component		Connected With	Result
Arduino Uno	Attitude Sensor	- SCL Pin with SCL pin - SDA pin with SDA	Connected

	Heading Sensor	- SCL pin with SCL Pin - SDA pin with SDA pin	Connected
	Altitude Sensor	- SCL pin with SCL pin - SDA pin with SDA pin	Connected
	GPS Sensor	- D4 pin with RX pin - D5 pin with TX pin	Connected
	Wifi Modul	- RX pin with D1 pin - TX pin with D2 pin	Connected

2.3.9 Detection Testing

Detection testing is a test to compare the value obtained by the sensor with the actual value or similar sensor so that the difference can be known from the value obtained.

1. Attitude Sensor Testing
   Attitude Sensor testing is comparing the angle value obtained from the sensor with the actual value.

Table 2. Pitch Angle Testing

Experiment	Actual Angle	Data Sensor	Difference
1	0^o	0^o	0^o
2	45^o	43^o	2^o
3	90^o	89^o	1^o
4	-45^o	-46^o	1^o
5	-90^o	-87^o	3^o

Table 3. Roll Angle Testing

Experiment	Actual Angle	Data Sensor	Difference
1	0^o	0^o	0^o
2	45^o	46^o	1^o
3	90^o	89^o	1^o
4	-45^o	-42^o	3^o
5	-90^o	-91^o	1^o

2. Heading Sensor Testing
   Heading sensor testing comparing the sensor value with the compass value.

Table 4. Heading Sensor Testing

Direction	HMC5883L	Compass	Difference
Utara	356	0^o / 360^o	4^o
timur	97	90^o	7^o
Selatan	181	180^o	9^o
barat	262	270^o	8^o

3. Altitude Sensor Testing
   Altitude sensor testing is done by comparing the sensor value with the altitude sensor value on the smartphone.

Table 5. Altutude Sensor Testing

Experiment	Location	Sensor Values	Sensor Values on Smartphone	Difference
1	Jl. Sukaluyu	695 Mdpl	702 Mdpl	7 Mdpl
2	Jl. Pahlawan	686 Mdpl	680 Mdpl	6 Mdpl
3	Gor C-Tra	681 Mdpl	692 Mdpl	11 Mdpl
4	UNIKOM	745 Mdpl	757 Mdpl	12 Mdpl
5	Monumen Perjuangan	721 Mdpl	734 Mdpl	13 Mdpl

4. GPS Sensor Testing
   GPS sensor testing is done by comparing the value of the sensor with the value of the GPS sensor on a smartphone.

Table 6. Testing Longitude Sensor Values

Experiment	Location	Sensor Values	Sensors Values on Smartphone	Difference
1	Jl. Sukaluyu	107.630432	107.630542	0.000110
2	Jl. Pahlawan	107.635665	107.635631	0.000106
3	Gor C-Tra	107.640121	107.640227	0.000106
4	UNIKOM	107.615165	107.615223	0.000058
5	Monumen Perjuangan	107.618049	107.618082	0.000033

Table 7. . Testing Longitude Sensor Values

Experiment	Location	Sensor values	Sensor values on Smartphone	Difference
1	Jl. Sukaluyu	-6.895126	-6.895222	0.000096
2	Jl. Pahlawan	-6.892862	-6.892879	0.000017
3	Gor C-Tra	-6.893804	-6.893965	0.000161
4	UNIKOM	-6.886882	-6.886937	0.000055
5	Monumen Perjuangan	-6.893602	-6.893779	0.000177

2.3.10 Testing time of Sending Data to the Database

Testing Time of sending data to the database is done by calculating the length of time needed to send data to the database.

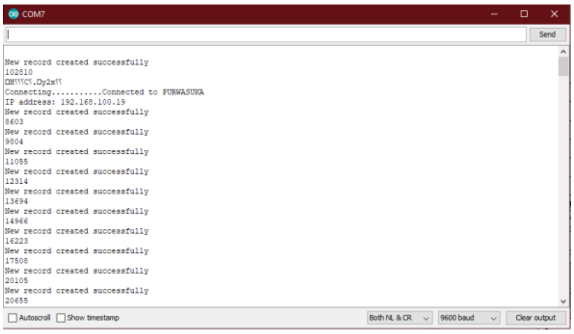


Figure 20. Data Delivery Time Testing

From the test results it can be seen that the time for the wifi module to connect to the internet takes about 8 seconds. And with the ten data sending sample, starting from the first data that was successfully sent at 8 seconds until the tenth data that was successfully sent at 20 seconds took about 12 seconds. Then in 1 data transmission it takes about 0.84 seconds.

2.3.11 Testing tool data retrieval and sending data to the database

Testing the data collection tool and sending data to the database is done with two conditions. The first condition inside the room and the second condition outside the room. The data taken is the attitude sensor data, location, altitude, and heading. Which will be sent to the database using the ESP8266 module.

Table 8. Testing data collection and delivery inside the room

Experiment	Testing Result					percentage of success
	Attitude	Location	Altitude	Heading	Data Sending	
1	B	G	B	B	B	80%
2	B	G	B	B	B	80%
3	B	G	B	B	B	80%
4	B	G	B	B	B	80%
5	B	G	B	B	B	80%
Total						400%
Average						80%

Explanation :

B : Success

G : Fail

Table 9. Testing data collection and delivery Outside the room

Experiment	Testing Result					Precentage of Success
	Attitude	Location	*Altitude*	*Heading*	Data Sending	
1	B	G	B	B	B	80%
2	B	B	B	B	B	100%
3	B	B	B	B	B	100%
4	B	B	B	B	B	100%
5	B	B	B	B	B	100%
Total						480%
Average						96%

Explanation :

B : Success

G : Fail

2.3.12. Functionality Testing

This functionality test stage uses blackbox testing, which focuses on the functional requirements of the application.

Table 10. Functionality Testing

No	Testing item	Testing Details	Type
1	Login	Insert Username and password	blackbox
2	Select UAV	Select the UAV to be monitored	blackbox
3	Monitoring	Shows UAV monitoring information	blackbox
4	Update UAV	Fill in the Update UAV form	blackbox

5	Add UAV	Fill in the form added UAV	blackbox
6	Logging	Shows UAV logging data	blackbox
7	Logout	Exit the application	blackbox

The results of black box testing have been done done shows the application being built has good functionality, because almost all tests carried out yielded results in accordance with expectations.

3. CLOSING

3.1 Conclusion

Based on the results obtained from the research conducted in the preparation of the final project that refers to the research objectives, it can be concluded.

1. The application can display information from sensor data on the UAV in the form of maps, text, graphics, and flight instruments.
2. Web-based applications can monitor Unmanned Aerial Vehicle (UAV) from a distance so that it can facilitate the Supervisor in monitoring UAVs.
3. The application can display log data from many UAVs so that it can facilitate supervisors and controllers in conducting evaluations.

3.2 Suggestions

So that the Ground Control Station Unmanned Aerial Vehicle (UAV) application runs well, this application still needs development so that this application is perfect and can run as desired. Following are some suggestions for developing this system:

1. Because of the difficulty of the GPS sensor receiving signals when testing. It is hoped that for further research better GPS sensors will be used.
2. Because the data transmission still has a long delay, it is hoped that in future studies a better wifi module will be used.

BIBLIOGRAPHY

[1] M. Nurdiansyah, “Perancangan dan Implementasi Kontroler PID untuk Tracking Waypoint pada Sistem Navigasi UAV (Unmanned Aerial Vehicle) Berbasis GPS (Global Positioning System),” Seminar, pp. 1–8, 2011.

[2] A. A. Farghani, R. Sumiharto, and S. B. Wibowo, “Purwarupa Ground Control Station untuk Pengamatan dan Pengendalian Unmanned Aerial Vehicle Bersayap Tetap,” Indones. J. Electron. Instrum. Syst., vol. 3, no. 1, pp. 1–10, 2013.

[3] F. A. Sianturi, “Perancangan Aplikasi Pengamanan Data Dengan Kriptografi Advanced Encryption Standard (AES),” Pelita Inform. Budi Darma, vol. 4, no. 1, pp. 42–46, 2013.

[4] E. D. Meutia, “Internet of Things – Keamanan dan Privasi,” Semin. Nas. dan Expo Tek. Elektro 2015, pp. 85–89, 2015.

[5] G. T. Mardiani, “Sistem Monitoring Data Aset dan Inventaris Universitas Komputer Indonesia Jurnal Ilmiah Komputer dan Informatika (KOMPUTA),” J. Ilm. Komput. dan Inform., 2013.

[6] Pressman and S. Roger, “Software engineering: A practitioner’s approach,” Adv. Eng. Softw., 2008.

[7] B. Firman, “Implementasi Sensor IMU MPU6050 Berbasis Serial I2C pada Self-Balancing Robot,” J. Teknol. Technoscientia, 2016.

[8] S. Sugandi, “Auto Tracking dan Satellite Finder untuk Antena Parabola dengan menggunakan Kompas Hmc5883l dan Bluetooth Hc05 Berbasis Android,” pp. 1–8.

[9] D. Kurniawan, A. N. Jati, and A. Mulyana, “Perancangan Dan Implementasi Sistem Monitor Cuaca Menggunakan Mikrokontroler sebagai Pendukung Sistem Peringatan Dini Banjir,” vol. 3, no. 1, pp. 3–9, 2016.

[10] A. Z. Arfianto et al., “Perangkat Informasi Dini Batas Wilayah Perairan Indonesia untuk Nelayan Tradisional Berbasis Arduino dan Modul GPS NEO-6M,” Joutica, 2018.